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EVALUATION OF DETERGENT RUBBER REMOVAL SYSTEM UNDER EXPEDITIONARY CONDITIONS IN SUPPORT OF OPERATION UNIFIED RESPONSE

Brian W. Cotter, Athar Saeed and Dean H. Hitzelberger
Applied Research Associates, Inc.
P.O. Box 40128
Tyndall Air Force Base, FL 32403-5323

Troy D. Thomas and Robert M. Wyatt
Airbase Technologies Division
Air Force Research Laboratory
139 Barnes Drive, Suite 2
Tyndall Air Force Base, FL 32403-5323

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TROY D. THOMAS, Major, USAF
Work Unit Manager

CHRISTOPHER L. GENELIN, Captain, USAF
Chief, Engineering Mechanics Section

ALBERT N. RHODES, PhD
Chief, Airbase Technologies Division

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*Cotter, Brian W.; *Saeed, Athar; *Hitzelberger, Dean H.;
**Thomas, Troy D.; **Wyatt, Robert M.

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7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
*Applied Research Associates
P.O. Box 40128
Tyndall Air Force Base, FL 32403

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** Air Force Research Laboratory
Materials and Manufacturing Directorate
Airbase Technologies Division
139 Barnes Drive, Suite 2
Tyndall Air Force Base, FL 32403-5323

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14. ABSTRACT

Buildup of rubber on runway surfaces is the leading cause of aircraft accidents upon landings. The skid resistance of a pavement surface depends on the friction developed between the pavement surface and the aircraft tire; skid resistance is significantly impacted by accumulation of rubber and is easy and reasonably inexpensive to restore. The Aircraft Operating Surfaces (AOS) research team at the Air Force Research Laboratory (AFRL) has over seven years of experience with runway friction measurements and developing lightweight C-130 deployable rubber removal capability for contingency environments.

15. SUBJECT TERMS

airfield pavements, runway friction, runway rubber removal, skid resistance, detergent rubber removal, water banking

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1. INTRODUCTION

1.1. Background

According to a report by the Australian Transport Safety Bureau (ATSB), between 1998 and 2007, 141 runway excursion accidents happened worldwide[1]. Included in these accidents were aircraft running off the end of the runway or departing the side of the runway, which resulted in 550 fatalities. Over 85 percent of these incidents took place during landings[2]. There are several factors that contribute to aircraft runway accidents; however, runway rubber build-up is one that is easy to recognize and reasonably inexpensive to correct.

The skid resistance of an aircraft operating surface depends on the friction developed between the pavement surface and the aircraft tire. This friction is dependent on the macro and micro texture of the pavement surface, surface smoothness, and the ability of the surface to drain. The most common factor for the deterioration of skid resistance is the accumulation of rubber on the pavement surface. Rubber is deposited every time an aircraft lands on a runway. The friction created from the motionless wheels touching down on the pavement surface can leave more than a pound of rubber with each landing. With each subsequent landing additional rubber is being deposited and at some point the friction characteristics of the landing area become an unacceptable risk to aircraft and passengers. Airfield managers can take a relative measurement of the friction with a decelerometer in their vehicle and get an idea of the coefficient of friction (COF) for the runway surface. Build-up of rubber lowers friction values and increases stopping distance. A significant number of airfields in the United States have a regular rubber removal schedule in order to stay in compliance with Federal Aviation Administration (FAA) regulations. FAA AC 150-5320-12C provides airport personnel with guidance on how to construct, maintain and assess skid resistant airfield pavement surfaces[3]. It describes common rubber removal techniques and provides guidance on how to properly accomplish this task.

1.2. Operation Unified Response

The 7.0 magnitude earthquake that shook Haiti January 2010 received world-wide attention and massive humanitarian aid support from all around the globe. After the United States took over airfield operations at Toussaint Louverture International Airport in Port-au-Prince (PAP)[4],Haiti, the Air Force Civil Engineer Support Agency (AFCESA) pavements evaluation team assessed pavement conditions for the OPERATION UNIFIED RESPONSE airlift. The evaluation team noted medium to medium–heavy rubber build-up on the 40-year-old runway. The increased air traffic (200 flights per day as opposed to 13 per day normally) in support of OPERATION UNIFIED RESPONSE significantly increased the rubber build-up on the runway surface in a short period of time. Left unattended, the increased rubber would have posed a significant safety risk.

1.3. Objective and Scope of Work

AFCESA relayed a request from Southern Command to Air Force Research Laboratory (AFRL) asking for personnel and equipment to remove rubber from the runway surfaces at PAP. AFRL/RXQ stood up the Unified Response Runway Rubber Removal Team to address the issue and conduct a field evaluation of their rubber removal equipment. The response team was composed of members from AFRL/RXQ and Applied Research Associates (ARA), Inc. , at Tyndall Air Force Base in Panama City, Florida. Priority was given to the request from Southern Command due to the expected drawdown of personnel, airlift support, relief activity, and the resumption of normal commercial flights. The team was asked to identify and clean the touchdown areas without impacting the daily operation of the busy airport schedule; therefore a night-time operation was required.

The overall objective of this infield assessment is to evaluate the C-130 transportable rubber removal equipment developed by AFRL and assess its effectiveness to dissolve and remove embedded rubber particles from within the micro- and macro-texture of airfield runways under expeditionary conditions. Previous in field tests helped establish which commercially available detergent is most effective in cleaning the runway surface. The product that has performed best overall in previous tests was used on the mission in support of OPERATION UNIFIED RESPONSE. This detergent has an application rate of 55 gal/10,000 sq ft, so 20 55-gal barrels were transported to Haiti to clean 200,000 sq ft of the runway.

1.4. Report Organization

Section 2 of this report describes the C-130 deployable rubber removal system developed by AFRL. Section 3 summarizes the logistical details mobilization to Haiti and some of the challenges that were overcome. Section 4 details rubber removal at PAP. Section 5 describes demobilization to the home station and associated challenges. Section 6 provides conclusions and recommendations for future improvements.

2. RUBBER REMOVAL SYSTEM

2.1. AFRL's Expertise with Detergent Removal Systems

AFRL has been actively looking at methods and alternative technologies for rubber removal in military applications[5]. In the last three years the team has developed the use of mobile, commercially available equipment that can be modified to remove runway rubber build-up and has been configured to be air transportable. To service potential forward operation locations, the developed system is C-130 transportable and requires minimal logistical support (only water and fuel) when placed in the deployment zone.

2.2. C-130 Deployable Chemical Detergent Removal System

The basic system consists of a Bobcat Toolcat® with angle broom attachment, an agricultural sprayer system in the bed of the Toolcat®, a water trailer and rubber removal detergents. The Bobcat Toolcat® was originally chosen for its agility and versatility in the field. It is a highly configurable platform that has the ability to accomplish a wide variety of tasks by utilizing multiple attachments. Figure 1 shows the detergent rubber removal system scrubbing the runway surface after application of the rubber removal detergent. The water spray bar uses high pressure water (at 40 psi) to push the cleaning residue off the pavement surface (Figure 2).

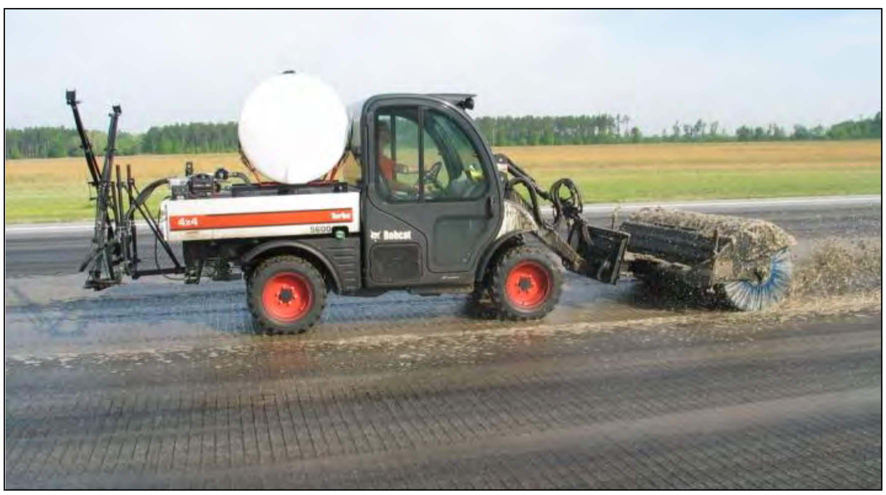

Figure 1. The Detergent Rubber Removal System in Operation at North Field

The Toolcat ® presents a lightweight, compact, and easily C-130 transportable platform. It has a 56-hp turbo diesel and is capable of achieving a top speed of 18 mph. The high degree of maneuverability makes it a logical choice for confined areas and all-wheel steering adds to its maneuverability.

The broom attachment (Figure 3) is a standard Bobcat® accessory for the Toolcat®. AFRL modified the configuration of poly- and steel-bristle wafers to provide adequate scrubbing and water movement capabilities when used in conjunction with the rubber removal detergents. The Toolcat's 26-gal/min high-flow hydraulic system is well suited for this application.

Figure 2. Water Spray Bar Folds Out to Push Rubber Residue Off the Pavement

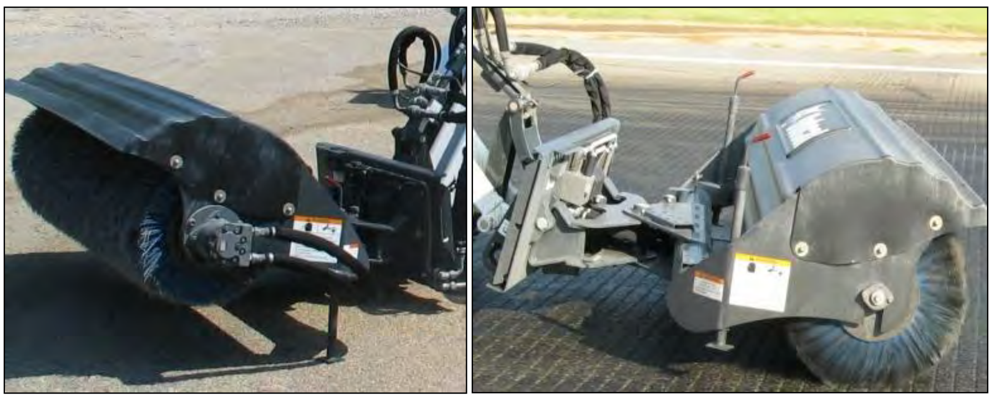

Figure 3. The System Uses the Broom Attachment to Scrum the Chemical

The AFRL-modified agricultural sprayer system (Figure 4) includes a 200-gal poly tank, gas-powered pump, and 21-ft wide folding sprayer boom (Figure 5). Initial testing started with a smaller tank and pump system that was inadequate for rubber removal requirements. The new system is capable of supplying 20 gal/min at a pressure of 40 psi. The 200-gal polyethylene horizontal storage tank can store sufficient rubber removal detergent to treat approximately 40,000 sq ft of runway surface, depending on the thickness of the rubber build-up.

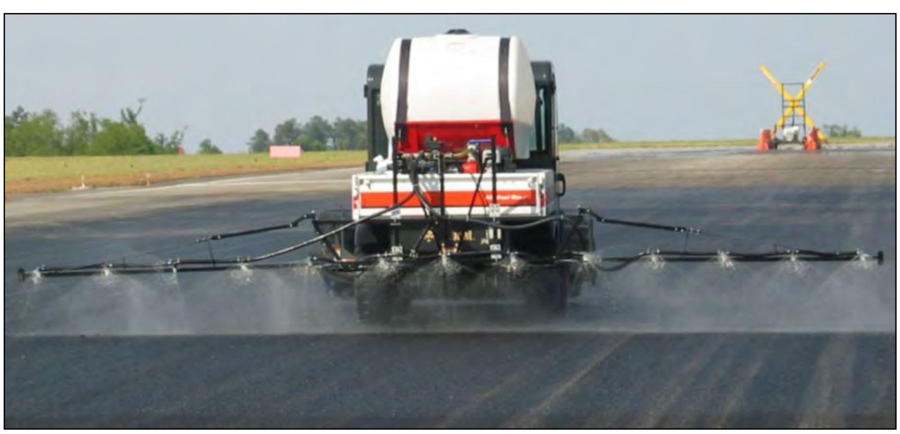

Figure 4. The Folding Water Spray Bar in Use

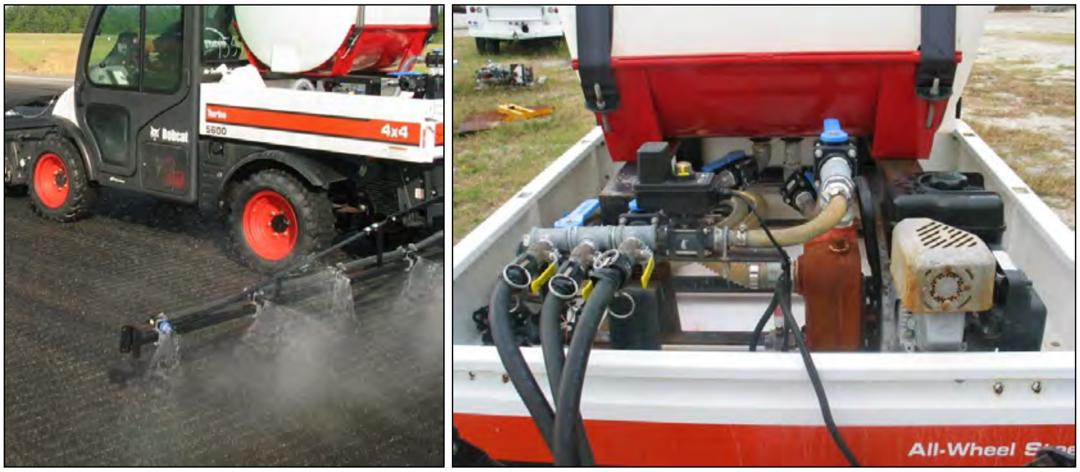

Figure 5. The Folding Spray Bar System Includes a Pump and Water Tank

2.3. Water Rinse Down System

The water rinse down (transformer) trailer, shown in Figure 6, was custom designed to meet the 463L pallet requirements of a C-130 aircraft and provide a variety of options of transport and load configuration. During the rubber removal operation it contains a 2000-gal water bladder and water distribution system. The bladder can be filled in minutes from a fire hydrant and towed to the cleaning area. During transport it holds tool boxes, attachments, supplies and additional items.

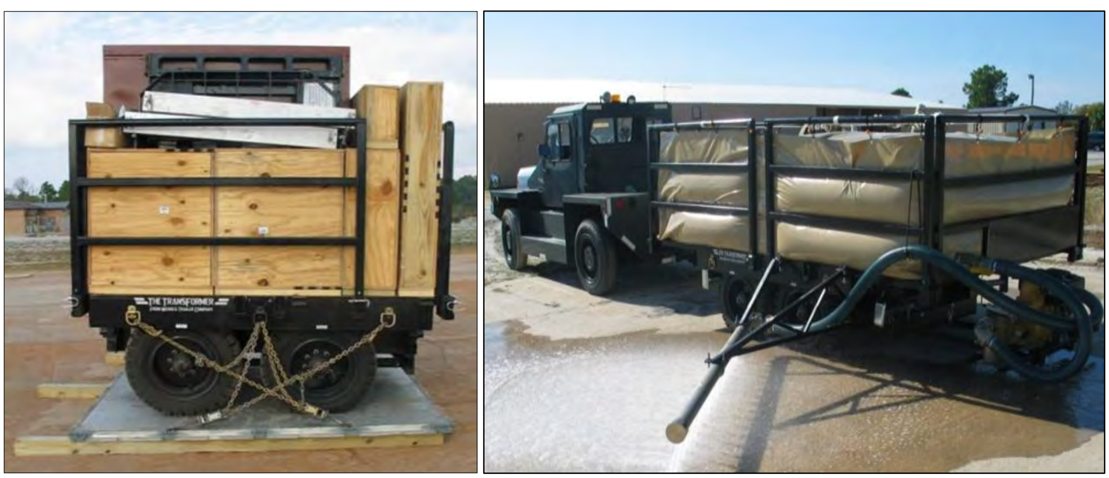

Figure 6. The Foldable Water Rinse Down System

3. OPERATION UNIFIED RESPONSE MOBILIZATION

3.1. Introduction

AFRL deployed a four-person team to the area of responsibility (AOR). The team consisted of an AFRL/RXQ military member and three ARA contractor personnel (senior field engineer and two engineering technicians).

3.2. Pre-Deployment Preparation

Predeployment preparations included palletizing the equipment, personnel getting the proper immunizations, obtaining country clearances, acquiring the rubber removal detergent, packing all tools and working with the local Transportation Management Office (TMO) personnel to schedule a dedicated flight for the deployment to the AOR. The entire response team participated in some measure with the predeployment preparations and detergent acquisition.

3.3. Deployment to Haiti

The deployment commenced 13 March 2010 after several attempts to arrange for an airlift aircraft. Figure 7 shows the Toolcat® being loaded into the C-17 aircraft. The Toolcat® was backed into the C-130 under self power without the need of any additional ramps or accessories.

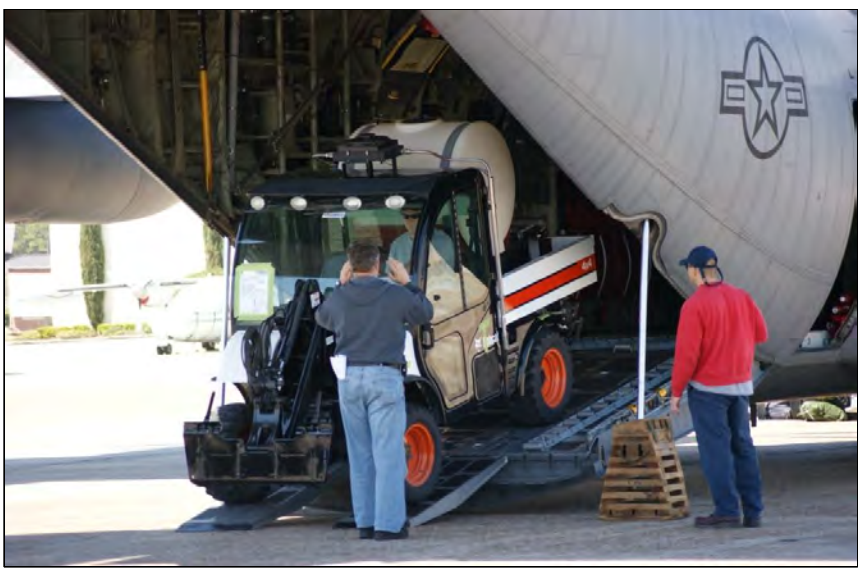

Figure 7. Loading Equipment in the C-17 Aircraft

The deployment equipment loading sequence was:

1. Toolcat®
2. 463L pallet full of detergent
3. 463L pallet with remaining detergent
4. Transformer trailer
5. Tail position – 463L pallet with broom attachment
6.

The detergent of choice was Avion50® based on past experience.   Several detergents were previously investigated for other research efforts and Avion50® was selected for detailed evaluation during this deployment. The detergent pellets were loaded onto the K-Loader (25,000 lbs capacity) for loading onto the C-130 aircraft (Fig. 8).

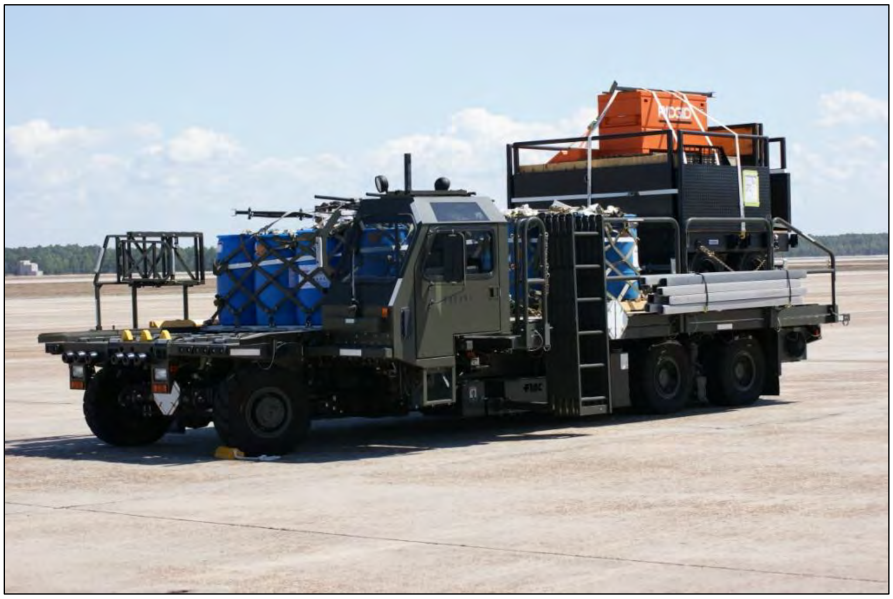

Figure 8. Equipment and Detergent Pellets Were Loaded Using the K-loader

3.4. Staging Equipment for Rubber Removal

All the equipment was shipped to a large field that was being used as a staging area for incoming and outgoing equipment (Figure 9). The response team accomplished several activities the first day in the morning in preparation of the first day (night) of cleaning. The following list of the activities helped set up the detergent rubber removal system:

- Unstrapped the transformer trailer from the 463L pallet and removed the trailer with a 10K all-terrain fork lift.
- Removed the side rails from the transformer trailer to use the Toolcat® with the forks attachment to unload all job boxes and crates from the trailer.
- With the trailer unloaded, the next step deployed the trailer to its full operating setup (Figure 10).
- Once the trailer was set up, the liner and the water bladder were installed (Figure 11).
- After the bladder was installed, the water pump and the spray bar were attached and all plumbing was connected. At this point the trailer was ready to be filled with water and put to use.
- The Toolcat® was set up next by installing the spray bar on the back of the Toolcat® (Figure 12), hanging the magnet and changing the forks attachment to the broom attachment.

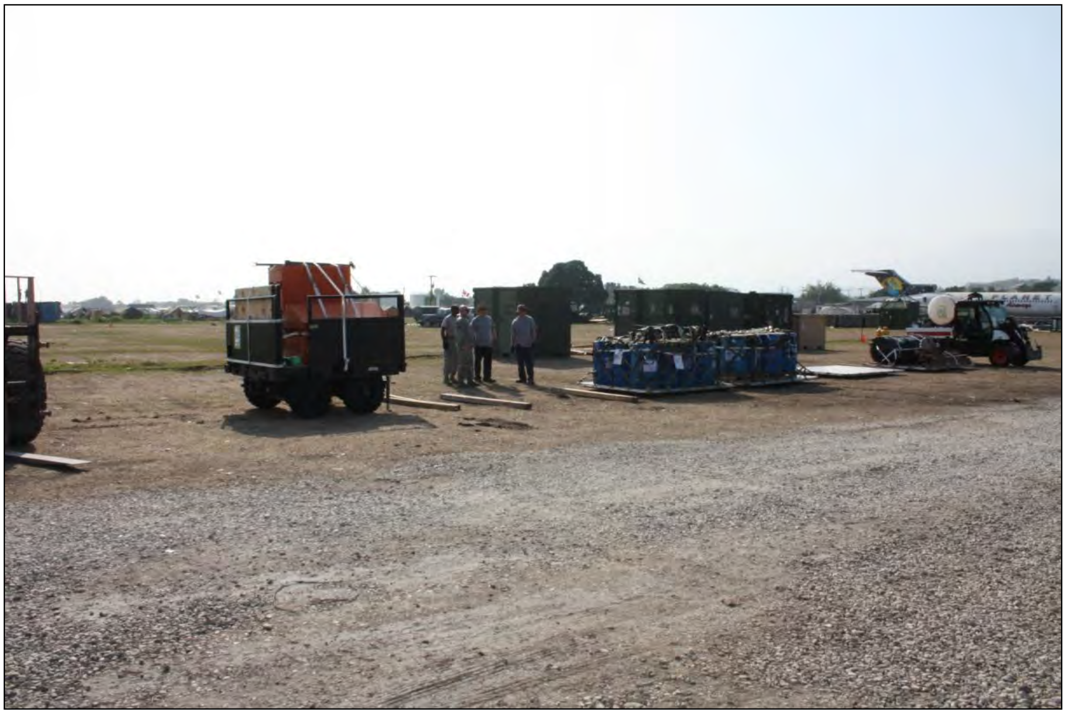

Figure 9. Equipment Staging Area at Port-Au-Prince Airport, Haiti

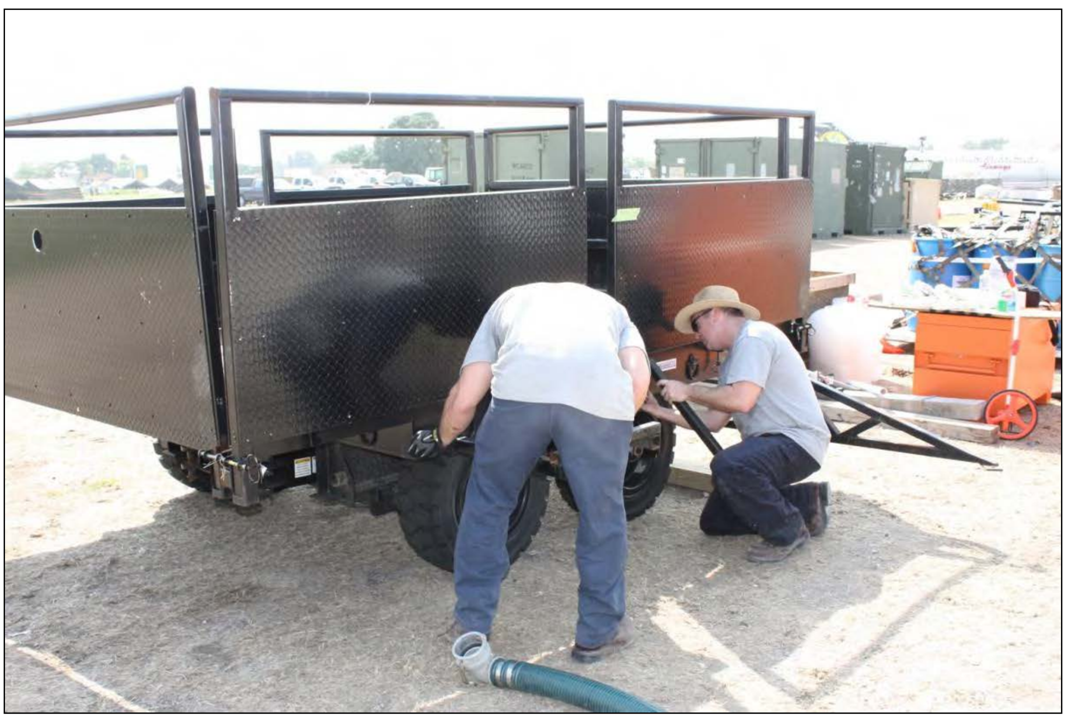

Figure 10. Transformer Trailer Being Set up in Preparation for Work

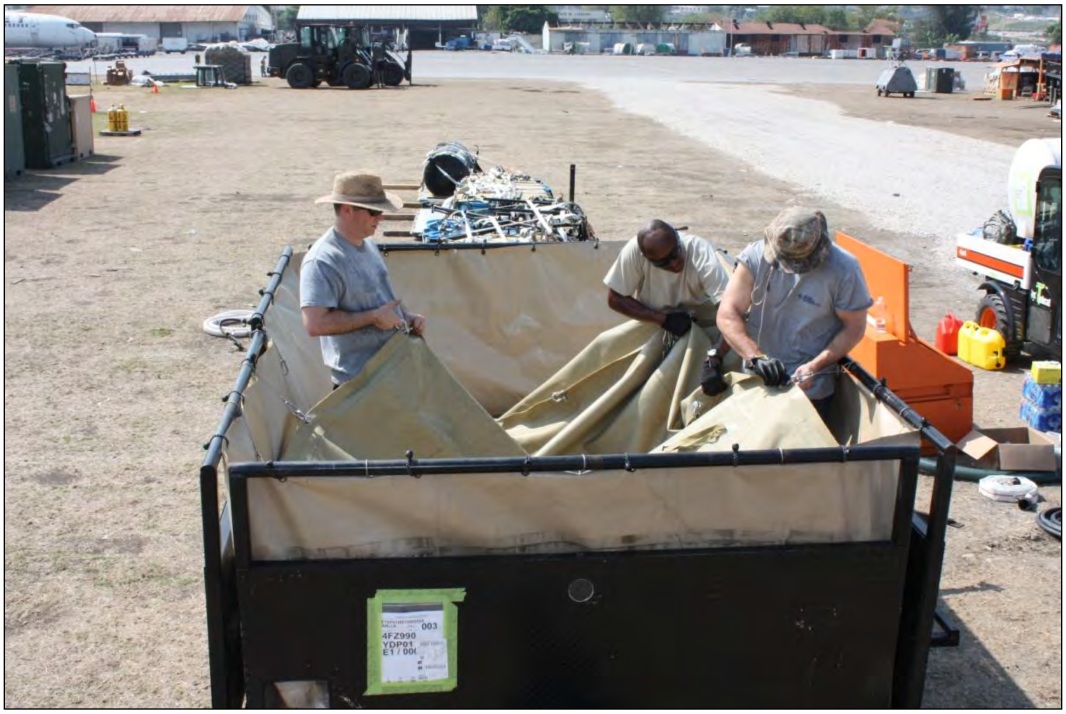

Figure 11. Water Bladder is Unfolded and Anchored in the Trailer to Carry Water

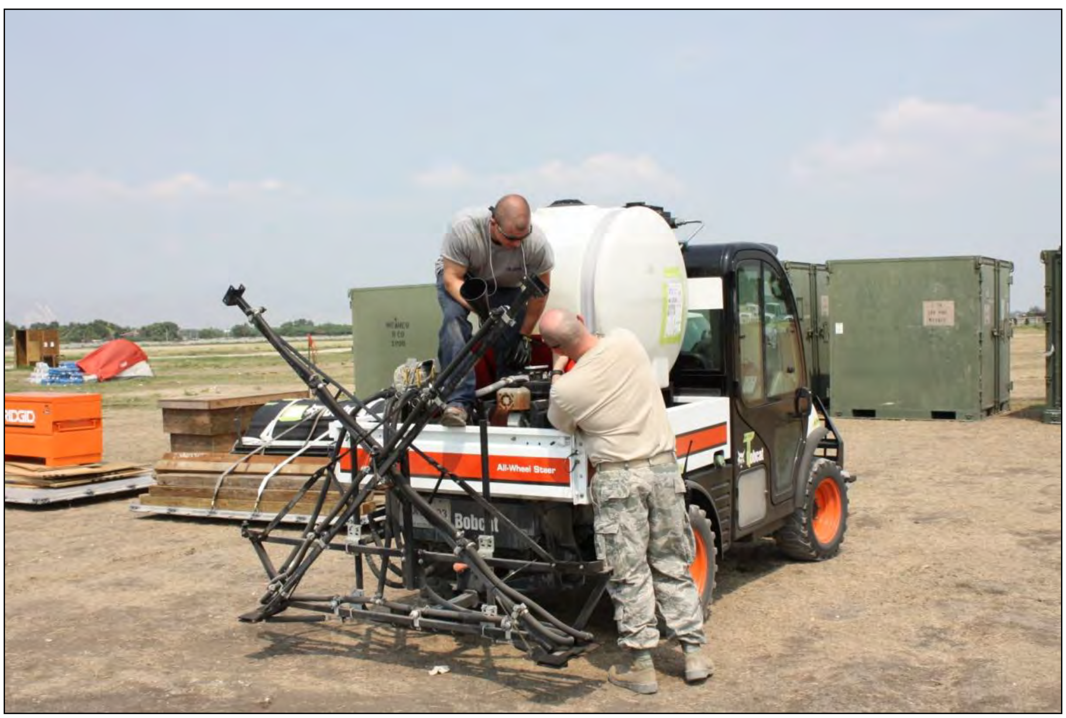

Figure 12. The Toolcat® Spray Bar Attachment Being Connected

After accomplishment of the above tasks, the equipment package was ready to go to work. The only infield support the system needs is water and fuel. After the equipment had been set up, the

Toolcat® pump, the pump on the transformer trailer, the Toolcat® and the reserve gas cans were filled with fuel. The water bladder on the transformer trailer (Fig. 13) was filled about 30 min prior to starting work on the runway for the first night.

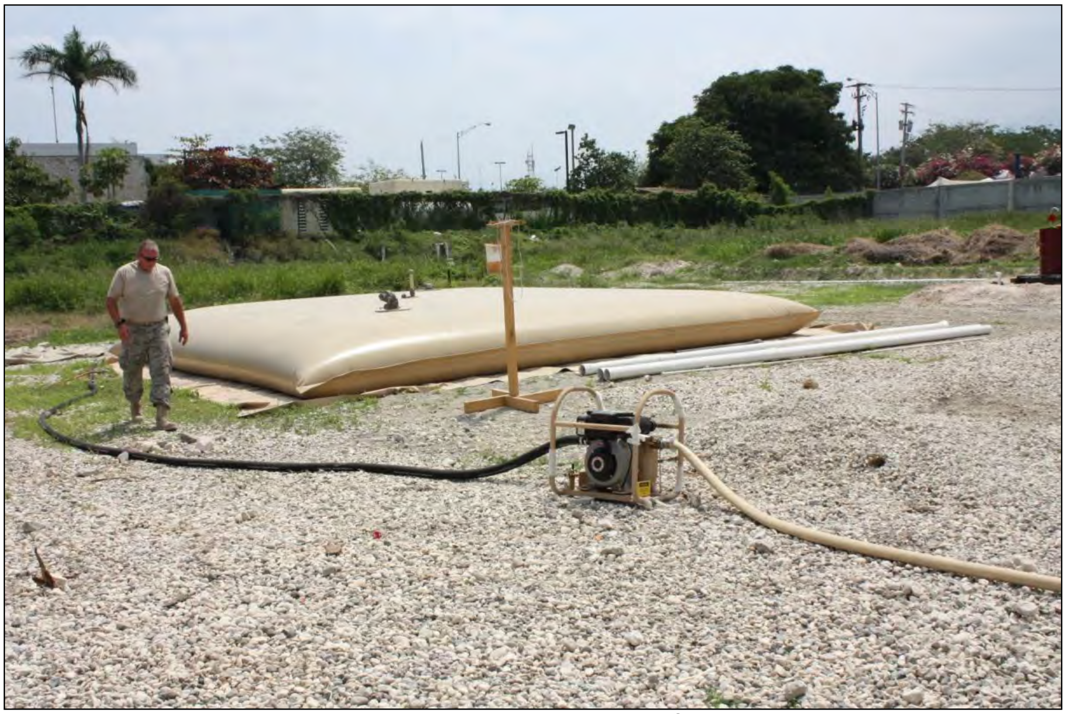

Figure 13. Water Being Transferred to Toolcat® and Transformer Trailer

4. RUBBER REMOVAL AT PORT-AU-PRINCE INTERNATIONAL AIRPORT

4.1. Initial Assessment and Plan of Action

After an initial survey of the condition of the runway, a plan for the operations was established and work began to stage the equipment and rubber removal detergents. In the weeks leading up to the deployment by AFRL the Airfield Pavements Evaluation Team (APE) from AFCESA had conducted and full evaluation of PAP Runway 10-28 and reported that the rubber build-up was medium to heavy over the touchdown and deceleration areas. This accumulation is visible in the image of the layout and Runway 10-28 at PAP shown in Figure 14.

Figure 14. Layout of Runway 10-28 and Apron at PAP

Once on the ground in Haiti, the response team conducted a cursory survey of Runway 10-28 to determine the area most affected by rubber build-up. The cursory survey indicated that the rubber build-up was medium to heavy on both the 10-end and the 28-end of the runway. However, because the primary end of the runway is the 10-end, its rubber build-up affected a much larger area. Approximate calculations indicated that 125,000 sq ft needed to be cleaned on the 10-end of the runway and approximately 75,000 sq ft on the 28-end of the runway.

The area to be cleaned on the 10-end of Runway 10-28 exceeds the cleaning capability of the equipment for a single 8-hour application; therefore, the 125,000 sq ft area was cleaned in two 8-hour shifts. Per manufacturer‘s recommendation the application rates are 55 gal of detergent and 3,000 gal of rinse water per 10,000 sq ft.

The rubber removal operation was divided into three phases shown in Figure 15. Table 1 shows calculated application rates of both detergent and rinse water.

Figure 15. Phases for Evaluation of the Detergent Rubber Removal System

Table 1. Calculated Application Rates for Detergent and Rinse Water

Phase	Area Cleaned (sq ft)	Detergent (gal)	Rinse Water (gal)
I	62,500	357.5	19,500
II	62,500	357.5	19,500
III	75,000	385	21,000

4.2. Detergent Rubber Removal Process at PAP

The detergent rubber removal process consists of four steps: 1) spraying the detergent on the runway surface, 2) a soak cycle, 3) agitation and scrubbing, and 4) rinse down. This entire process is dependent on large amounts of water being available to keep the rubber removal detergent wet during the agitation and scrubbing phase and to rinse down the detergent from the treated area. The work was accomplished in three phases as indicated in Table 1. An in-field evaluation of the detergent rubber removal system was conducted by observing the system efficiency, water and detergent consumption rates and cleaning rate (time versus area cleaned).

4.2.1. Phase I – 10-end of Runway 10-28 (Near Threshold)

System evaluation on the first night (15 March 2010) consisted of cleaning 62,500 sq ft on the 10-end of Runway 10-28. The area cleaned was 1,250 ft x 50 ft beginning 500 ft from the 10-end threshold and extending to 1,750 ft from the 10-end of Runway 10-28 threshold (Figure 15).

The process began at 2210 local time under weather conditions listed in Table 2. A total of 375.5 gal of detergent were applied to the 1250-ft long cleaning area. The detergent was allowed 30 min to soak before agitation with the broom attachment of the Toolcat® began. Agitation began on the outermost sides of the cleaning area and traversed inward toward the centerline in 6-ft intervals with 2 ft of overlap moving across the 50-ft width and down the 1,250-ft length. The broom angle was such that the slurry pushed toward the centerline. Once centerline was reached, the Toolcat® followed the same path back, changing the broom angle to push outward and moved the slurry toward the edge of the runway. This back-and-forth cycle across the width was repeated continuously for the next 3.5 hrs. The rinse cycle began at 0320 and ended at 0550 local. Figure 16 shows the condition of the 10-end of Runway 10-28 before removal of accumulated rubber. Figure 17 shows the condition of the 10-end Runway 10-28 after rubber removal.

Table 2. Weather Conditions During Phase I of System Assessment

Weather Condition	Observed Data
Temperature (2215 local)	86° F
Temperature (0550 local)	79° F
Average Humidity	77%
Dew Point	74° F
Precipitation	0 in
Wind	4–12 mph

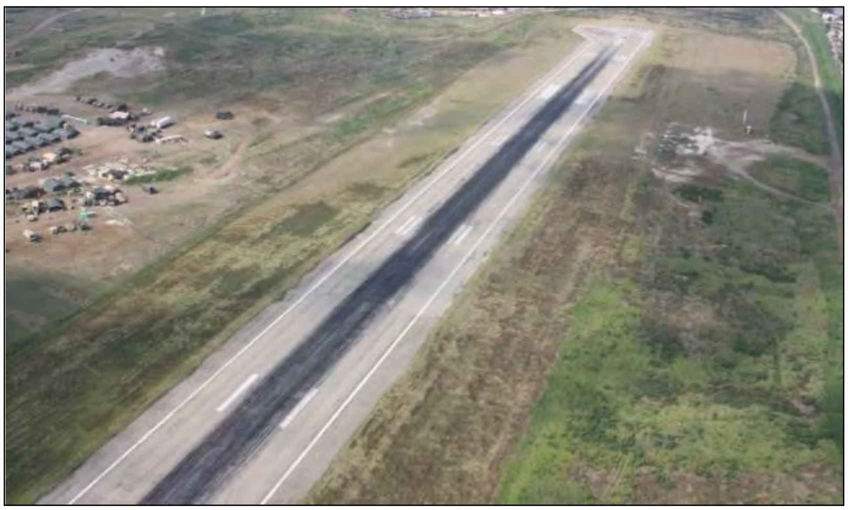

Figure 16. 10-end of Runway 10-28 Before Rubber Removal

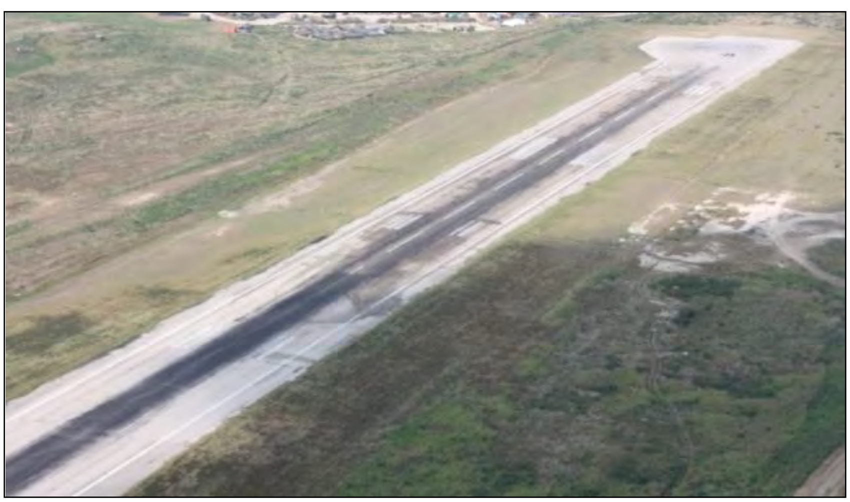

Figure 17. 10-end of Runway 10-28 After Phase I Rubber Removal

The rinse process called for 19,500 gal of rinse water; however, due to difficulties obtaining these large quantities of water in a timely manner, only 11,000 gal of water were used. The result of using less water is that the runway has a brown stained appearance. This brown staining is typical when cleaning with detergents; however the staining was slightly heavier due to the limited amount of rinse water used in the process. The brown staining usually will rinse away in a short time after a few rainfalls. However, the results of the cleaning were as good as or better than expected. Overall the process went well the first night with the exception of the shortage of available rinse water.

The Haitian contractor responsible for providing the requisite rinse water was not informed of the overnight operation and provided only a portion of the required water needed for rinsing (thus the staining shown in Figure 17). Alternate arrangements were made with the Fire Department to provide the additional water with one of their 5000-gal water tanker trucks for rinsing. It was decided that the team would borrow four 2,500-gal capacity onion bladders from the Fire Department to stockpile water for the second night of cleaning. During daylight hours the onion bladders were filled with water as shown in Figure 18.

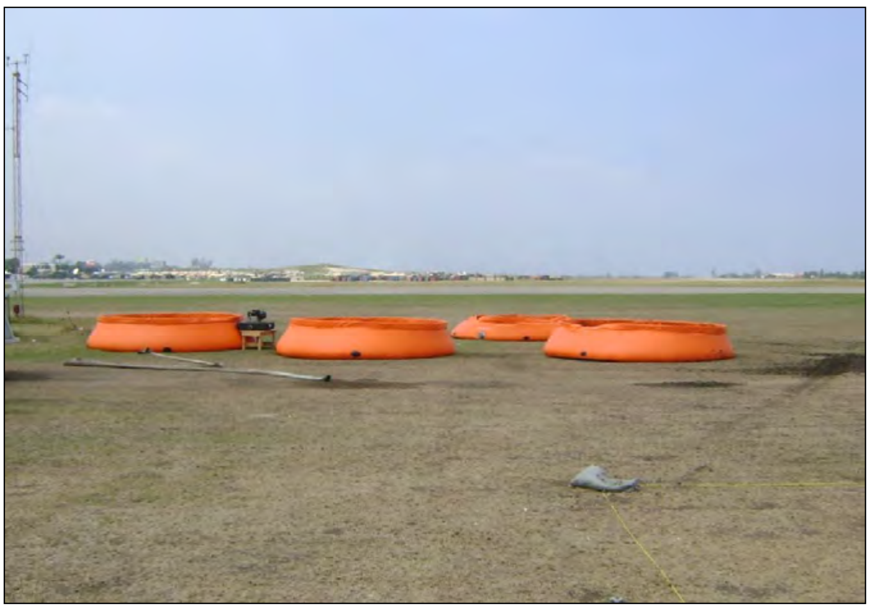

Figure 18. Four 2500-gal Capacity Onion Bladders Stored Water for Later Use

4.2.2. Phase II – Western End of Runway 10-28 (Away from Threshold)

The evaluation on the second night (16 March 2010) consisted of cleaning 62,500 sq ft on the 10-end of Runway 10-28 (away from the threshold). The area cleaned was 1,250 ft by 50 ft beginning 1,750 ft from the western threshold of Runway 10-28 and extending to 3,000 ft from the western end of Runway 10-28 (Figure 15). The assessment began at 2205 local time with application of the detergent under weather conditions listed in Table 3.

A total of 375.5 gallons of detergent were applied to the 1250-ft long test section. After the required 30-min soak time, the agitation process with the broom attachment began. The rinse cycle began at 0200 and ended at 0500. The rinse process called for 19,500 gal of rinse water;

Table 3. Weather Conditions During Phase II of System Assessment

Weather Condition	Observed Data
Temperature (2205 local)	85° F
Temperature (0500 local)	80° F
Average Humidity	76%
Dew Point	73° F
Precipitation	0 in
Wind	5–14 mph

however, only 12,000 gal of water were used. By utilizing the water banking system with the four 2,500-gal-capacity onion bladders delivery of water was to the runway much more consistent (i.e., very little downtime awaiting water delivery, which allows the detergent to dry). The results of this seamless water delivery along with good conditions allowed less water to be used than recommended to achieve the desired results. Although the cleaning process exceeded expectations the area will continue to lighten up with rainfall events. Figure 19 and Figure 20 compare the condition of Runway 10-28 before and after removal of the accumulated rubber.

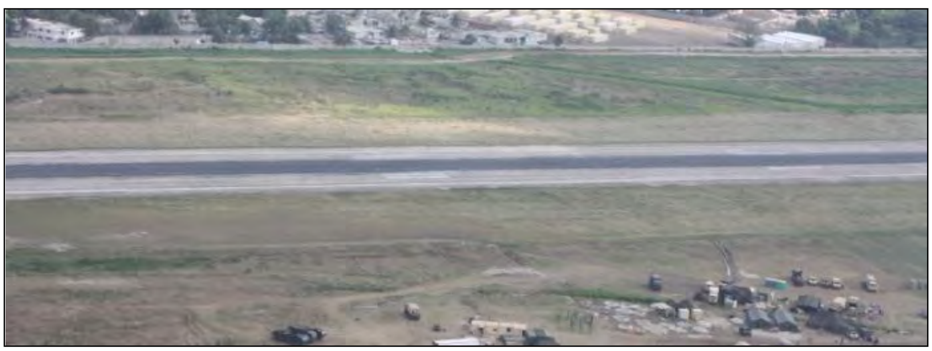

Figure 19. 10-end of Runway 10-28 Before Rubber Removal

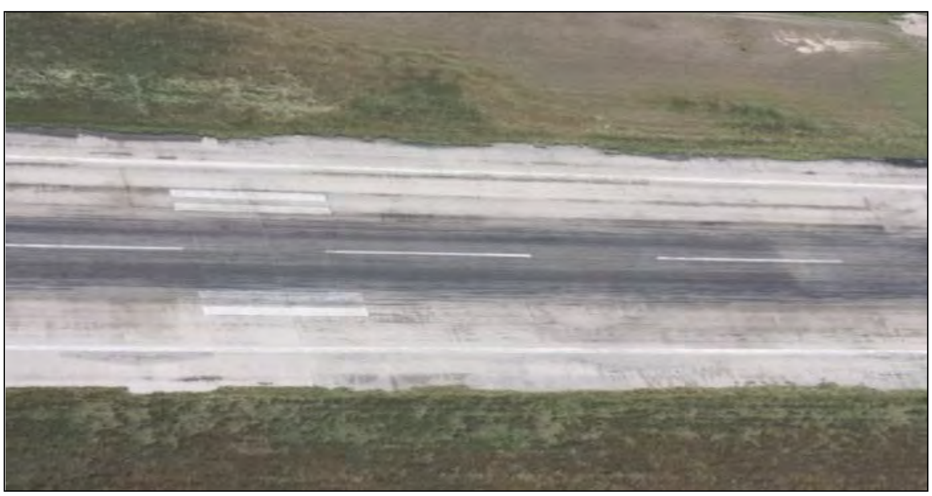

Figure 20. 10-end of Runway 10-28 After Phase II Rubber Removal

4.2.3. Phase III – 28-End of Runway/10-28 (Near Threshold)

The evaluation on the third night (16 March 2010) consisted of cleaning 75,000 sq ft on the 28-end of Runway 10-28. The area cleaned was 1,500 ft by 50 ft beginning 1,000 ft from the 28-end threshold and extending to 2,500 ft from the 28-end threshold (Figure 15). The process began at 2210 local time under the conditions listed in Table 4. It took 7 hours to clean this area.

Table 4. Weather Conditions During Phase III of System Assessment

Weather Condition	Observed Data
Temperature (2205 local)	85° F
Temperature (0500 local)	78° F
Average Humidity	73%
Dew Point	72° F
Precipitation	trace
Wind	6–16 mph

A total of 385 gal of detergent were applied to the test section. Before agitation began, the detergent was allowed 30 min to soak. The rinse cycle began at 0200 and ended at 0500. The rinse process called for 21,000 gal of rinse water; however, only 15,000 gal of water were used. Once again by utilizing the water banking system with the 2,500-gal capacity onion bladders water was delivered to the runway much more consistently. The results of this seamless water delivery along with good conditions allowed the team to use less water than recommended and achieve the desired results. Figures 21 and 22 compare the condition of Runway 10-28 before and after rubber removal.

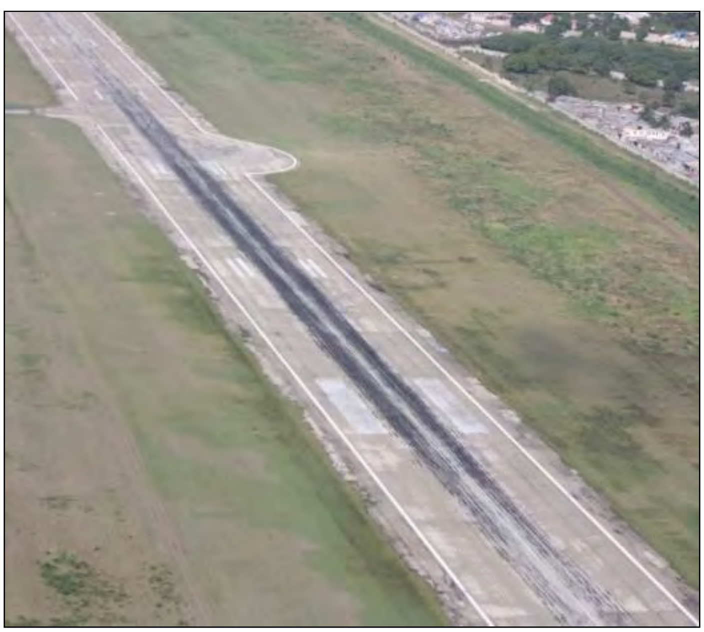

Figure 21. Eastern End of Runway 10-28 Before Phase III Rubber Removal

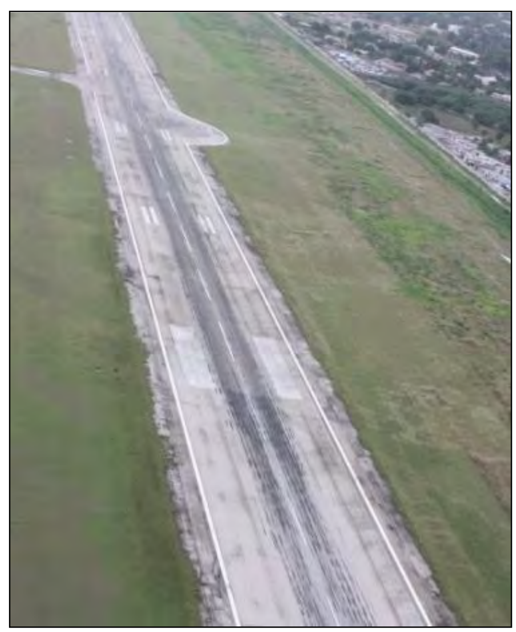

Figure 22. Easter End of Runway 10-28 After Phase III Rubber Removal

5. DEMOBILIZATION TO TYNDALL AFB

5.1. Introduction

Demobilization of the crew and equipment began after completing all rubber removal activities 18 March 2010. Due to drawdown of OPERATION UNIFIED RESPONSE the team secured airlift on 26 March 2010.

5.2. Cleanup and Packing

The crew cleaned all equipment prior to the airlift. Rubber removal detergent barrels were rinsed, cut in half (Figure 23) and properly disposed of by packing on pallets (Figure 24). All tools and equipment were also rinsed before packing for airlift (Figure 25 and Figure 26), re-palletized and prepared for return to Tyndall Air Force Base. The transformer trailer was rinsed (Figure 27), packed and rinsed again (Figure 28). The equipment was then staged on the apron in preparation for airlift (Figure 29).

Figure 23. Demobilization Included Rinsing and Cutting Detergent Barrels

Figure 24. Rinsed and Cut Barrels Were Disposed of on Pallets

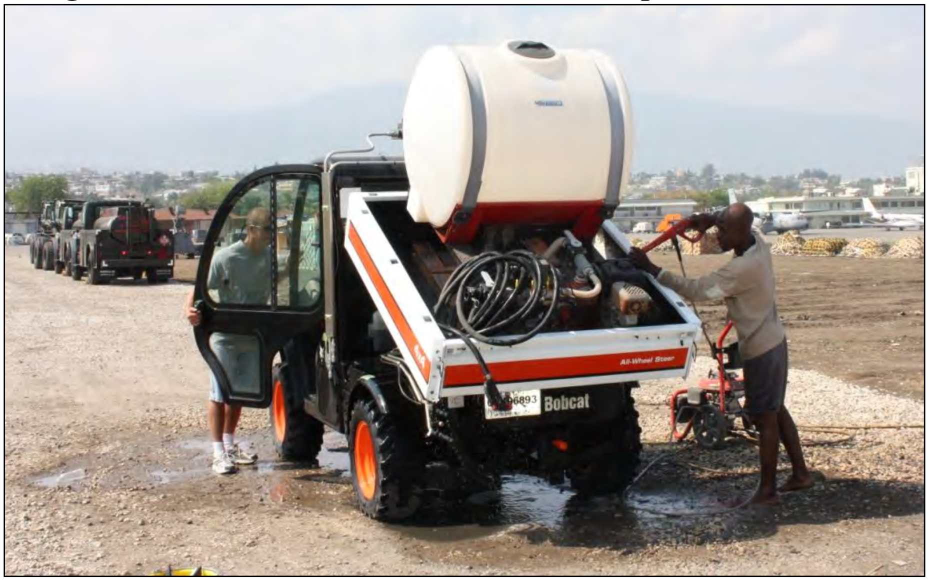

Figure 25. The Toolcat® Was Rinsed Prior to Demobilization

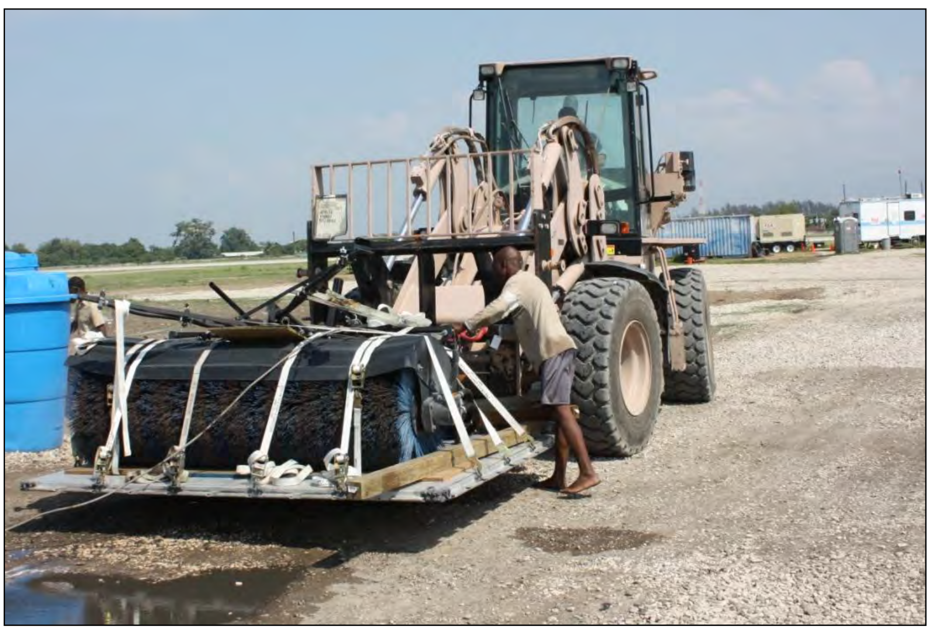

Figure 26. The Broom Attachment Was Palletized and Rinsed

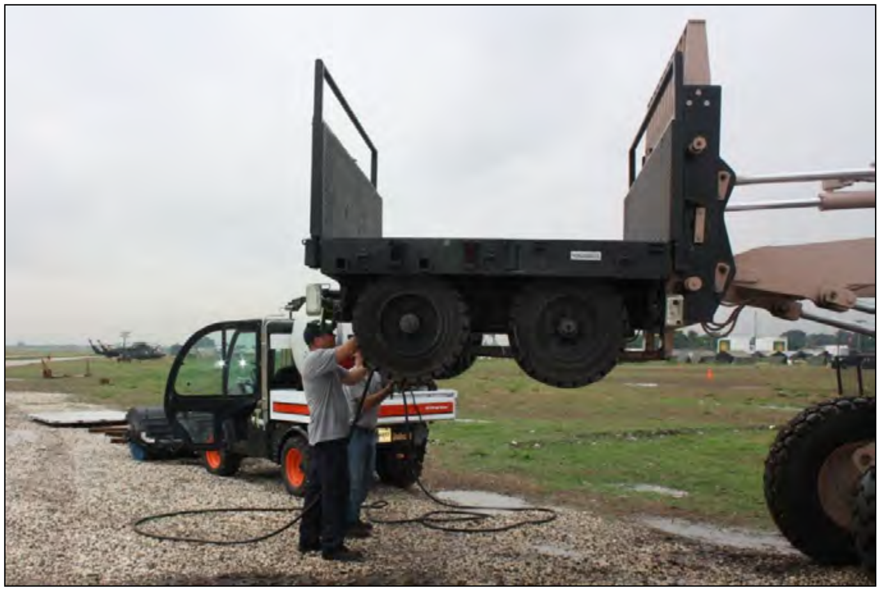

Figure 27. The Transformer Trailer Was Rinsed Before Packing

Figure 28. The Transformer Trailer Was Rinsed Again After Packing

Figure 29. After Cleaning, the Equipment Was Staged for Airlift

5.3. Assistance with Other Efforts After Completing Rubber Removal

After the equipment was prepared for airlift the response team assisted other deployed personnel with humanitarian (Figure 30) and airfield management (Figure 31) efforts in the local region.

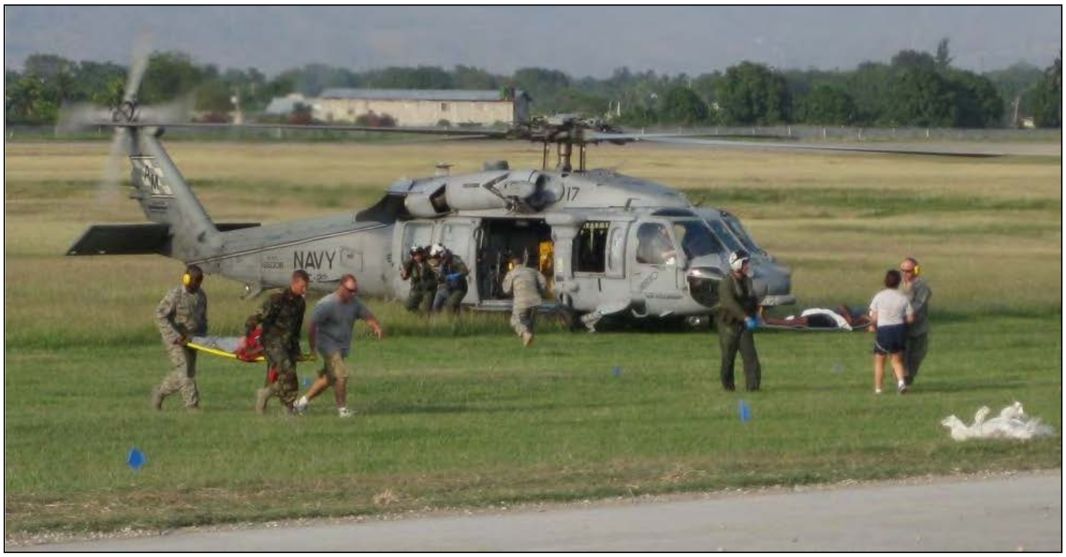

Figure 30. The Response Team Assisted with Humanitarian Efforts After Rubber Removal

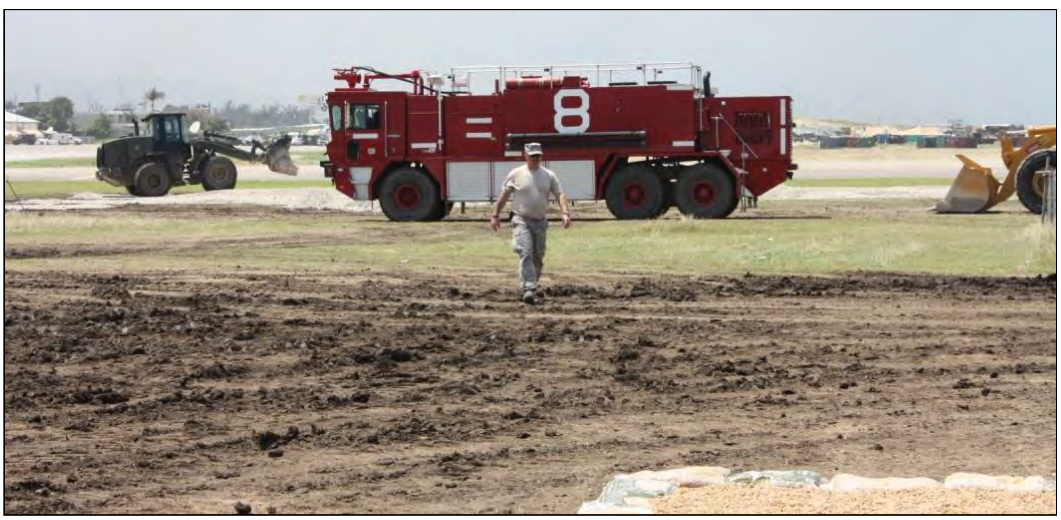

Figure 31. The Response Team Assisted with Construction at PAP After Rubber Removal

6. SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

6.1. Summary

The task of runway rubber removal at Haiti's Toussaint Louverture International Airport in PAP was completed without any problems. The area cleaned was approximately 200,000 sq ft with 1100 gal of chemical used. The effort was completed in three 8-hour shifts and many logistical issues were overcome.

6.2. Conclusions

The effort to remove the rubber from Toussaint Louverture International Airport provided a real-world test of the equipment in an expeditionary environment with no mechanical breakdowns or interruptions in the operation. The system proved the concept—a quick rubber removal operation is possible with minimum impact on flying operations.

6.3. Recommendations

Some recommendations for future improvement to the system were noted during field evaluation. The first would be to research a vehicle with higher hydraulic pressure output, to speed up the operation, but the ensuing tradeoff would be one of output for increased weight. The second item would be adding some of the 2500-gal onion type water bladders to the kit to make it more self sufficient. Had the Fire Department not been as accommodating as they were the operation would have suffered tremendously. It would also be of particular importance in the case of a contingency or expeditionary deployment to have improved communication with personnel at the site prior to departure to anticipate and transmit logistical requirements to the few but necessary support functions required to pull off an operation of this type.

7. REFERENCES

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LIST OF SYMBOLS, ABBREVIATIONS AND ACRONYMS

AFCESA	Air Force Civil Engineer Support Agency
AFRL	Air Force Research Laboratory (Detachment 2, Tyndall AFB, Florida)
AOR	area of responsibility
APE	Airfield Pavements Evaluation Team
ATSB	Australian Transport Safety Bureau
ft	feet
gal	gallons
hp	horsepower
in	inches
PAP	Toussaint Louverture International Airport, Port-au-Prince, Haiti
psi	pounds per square inch
sq ft	square feet
TMO	Transportation Management Office
°F	temperature in degrees Fahrenheit